MAPPING URBAN SETTLEMENT DYNAMICS: THE CASE OF SRI LANKANS IN FOUR ITALIAN CITIES[1]

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Abstract. This study explores the spatio-temporal dynamics of Sri Lankan settlement in four Italian metropolitan cities – Milan, Rome, Naples, and Catania – over the period 2011-2021. Employing high-resolution spatial grid (100×100 meters), we compute a Location Quotients (LQs) for the Sri Lankan population and examine its variation via Geographically Weighted Ridge Regression (GWRR) in each census year. Our models integrate structural, demographic, and socio-economic dimensions to capture localised influences on ethnic concentration, while a ridge penalty mitigates multicollinearity. Diagnostic metrics (AICc, Moran's *I*) confirm a generally adequate fit with moderate positive spatial autocorrelation in residuals. Results reveal clear north-south contrasts and evolving settlement patterns. Temporal comparisons indicate relative stability in Rome and Naples, contrasted by significant process of redistribution in Milan and Catania. By integrating fine-scale spatial data with GWRR, this work advances methods for studying non-stationary residential segregation patterns and offers insights for context-sensitive urban policy aimed at promoting spatial integration.

1. Introduction

Residential segregation, i.e., the spatial separation of distinct population groups within urban environments, has profound implications for social cohesion, access to opportunities, and the equitable distribution of resources (Massey and Denton, 1993; Peach, 1996). In Southern Europe, rapid and sustained immigration flows over the past few decades have reshaped urban landscapes, giving rise to both diffuse multiculturalism and localized ethnic enclaves (Malheiros, 2002; Benassi *et al.*, 2020). Italy, in particular, has witnessed distinctive settlement patterns among Sri Lankan migrants, who initially concentrated in major metropolises – Rome, Milan, and Naples – before radiating into suburban and peri-urban zones via labor-market and kinship networks (Ambrosini, 2013; Benassi *et al.*, 2015).

Despite a burgeoning literature on immigrant spatial assimilation, fine-scale analyses of Sri Lankans' settlement trajectories in Italian contexts remain few (Benassi *et al.*, 2023; Bitonti *et al.*, 2023). Existing studies tend toward group-

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specific case reports (Aspinall, 2019; Dharmadasa and Herath, 2020) or cross-city comparisons at coarse spatial resolutions (Benassi *et al.*, 2019; Maloutas and Arapoglou, 2016). The present work addresses this gap by employing high-resolution grid data and Geographically Weighted Ridge Regression (GWRR) to (i) compare spatial heterogeneity of settlement patterns across four divergent urban contexts: Milan, Rome, Naples, and Catania, and (ii) quantify temporal changes in Sri Lankan residential concentration between 2011 and 2021 censuses.

Our objectives are threefold:

1. Contextual variability: elucidate differences in their spatial distribution and clustering across metropolitan areas of different population size.
2. Driver identification: uncover structural (e.g., housing costs), demographic (e.g., population growth) and cultural (e.g., family size, immigrant network) predictors shaping these patterns.
3. Temporal evolution: assess how the Sri Lankan spatial concentration within the selected Italian cities evolved over a decade.

By integrating uniform 100×100 meters grid data with Geographically Weighted Ridge Regression (GWRR), this study advances methodological approaches for spatial non-stationarity in residential segregation research and informs policy strategies attuned to local dynamics and equity considerations.

2. Materials and methods

The analysis covers four Italian municipalities chosen for their divergent scales and socio-economic milieus: Milan and Rome (major northern and central metropolises) and Naples and Catania (southern metropolises).

The primary outcome is the Sri Lankans' Location Quotient (LQ), defined as the ratio of the Sri Lankan population share in each cell to its share in the total municipal population. A LQ>1 indicates over-representation relative to the municipal average, highlighting areas of ethnic concentration, conversely, LQ<1 suggests under-representation. Based on theoretical and empirical precedents (Brunsdon *et al.*, 1998; Fotheringham *et al.*, 2002), we considered the following predictors at cell level:

- Mean growth rate of Italian residents between 2001-2011, and 2011-2021 (Istat).
- Mean growth rate of all foreign residents between 2001-2011, and 2011-2021 (Istat).
- Proportion of foreign residents in 2011 and 2021 (Istat).
- Proportion of large families (≥ 5 members) in 2011 and 2021 (Istat).
- Employment rate of the population aged 15-64 in 2011 and 2021 (Istat).
- Proportion of individuals with no university degree in 2011 and 2021 (Istat).

– Minimum residential rent cost, obtained from the *Osservatorio del Mercato Immobiliare* in 2011 and 2021 (OMI, Italian Revenue Agency).

A regular lattice geography overlays each municipal boundary, providing a fine resolution for capturing micro-scale settlement clusters (Catney and Lloyd, 2020). Following an areal weighted interpolation technique, the source data referring to different spatial units (i.e., census enumeration areas and OMI zones) were rearranged to the target spatial units, that are the squared cells. For this analysis, we implemented two geographically weighted ridge regression models (GWRR), one for each census year considered, which extend the conventional geographically weighted regression (GWR) by adding a penalty term to stabilize coefficient estimates in the presence of multicollinearity. Unlike ordinary least squares (OLS), which fits one global equation and assumes that relationships between predictors and the outcome are spatially invariant, GWR fits a distinct regression at each location, weighting observations by their proximity to the target point. By further incorporating a ridge penalty (λ), GWRR shrinks coefficient magnitudes, thus improving numerical stability when predictors are highly correlated.

Concretely, for each centroid (with coordinates (u_i, v_i)) of cell i, we specify the local model as:

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k (u_i, v_i) x_{ik} + \varepsilon_i \quad (1)$$

where y_i is the Sri Lankans' LQ in cell i, x_{ik} the k-th covariate, and ε_i the error term (Fotheringham *et al.*, 2002). The regression parameters are estimated for each cell i independently by weighted least squares. The matrix calculation for the estimated regression parameters is:

$$\widehat{\boldsymbol{\beta}}(i) = [\boldsymbol{X}^T \boldsymbol{W}(\mathrm{i})\mathbf{X}]^{-1} \boldsymbol{X}^T \boldsymbol{W}(\mathrm{i})\mathbf{y} \quad (2)$$

where $\boldsymbol{X}$ is the matrix of predictors, the diagonal weight matrix; $\boldsymbol{W}(i) = diag[w_1(i), \dots, w_n(i)]$, varies with the cell i and assigns observation-specific weights; $\boldsymbol{y}$ denotes the vector of dependent variables; $\widehat{\boldsymbol{\beta}}(i) = (\hat{\beta}_{i0}, \hat{\beta}_{i1}, \dots, \hat{\beta}_{ip})^{\boldsymbol{T}}$ is the local regression coefficient vector at cell i; $(p+1)$ represents the number of coefficients. The weight w_{ij} follows a bisquare kernel:

$$w_{ij} = \begin{cases} \left[1 - (d_{ij}/b_i)^2\right]^2, & d_{ij} < b_i \\ 0, & otherwise \end{cases} \quad (3)$$

with d_{ij} the Euclidean distance between cells i and j, and b_i an adaptive bandwidth, defined by the number of nearest neighbours, that varies by location. The penalty parameter λ is chosen via global cross-validation and kept constant across all local models to ensure comparability (Hastie *et al.*, 2001). Optimal bandwidths are determined by minimizing the corrected Akaike Information Criterion (AICc),

balancing model fit and complexity. Finally, to verify the absence of unmodeled spatial structure, we applied Moran's I (Moran, 1948) test to the residuals of each local regression . All procedures were executed in R using the GWmodel package (functions bw.gwr() and gwr.ridge()) (Gollini *et al.*, 2015).

The data presented in Table 1 reveal divergent patterns of Sri Lankan residency across several Italian cities. In Milan and Rome, Sri Lankan settlement has expanded incrementally but remains proportionally moderate, likely reflecting the lure of diversified employment prospects and established urban infrastructures. Conversely, Naples has experienced a pronounced upswing, which highlights its emergence as a primary destination for this community. In Catania, despite their absolute growth, Sri Lankans' proportion over the total foreign population has decreased over time. This points to the distinctive demographic and economic dynamics of smaller southern municipalities.

Table 1 – *Sri Lankans residing in the four selected Italian municipalities in 2011 and 2021.*

Municipality	2011		2021	
	A.V.	% of foreigners	A.V.	% of foreigners
Milan	10,914	6.4	16,637	6.0
Rome	5,442	2.3	9,440	2.6
Naples	6,641	23.2	15,051	26.7
Catania	1,495	19.3	2,574	18.9
Total				0.08*

*Note: * = percentages relative to the total foreigners residing in Italy. Source: authors' elaborations on Italian General Population and Housing Censuses*

3. Results

Figure 1, depicting early-2021 data, reveals that the spatial configuration of the Sri Lankan population differs markedly between Italy's central/northern metropolises (Milan and Rome) and its southern cities (Naples and Catania). In Milan and Rome, Sri Lankan residents are dispersed broadly across the urban fabric, displaying no pronounced clustering. Conversely, in Naples and Catania the same community is predominantly concentrated within the core central districts.

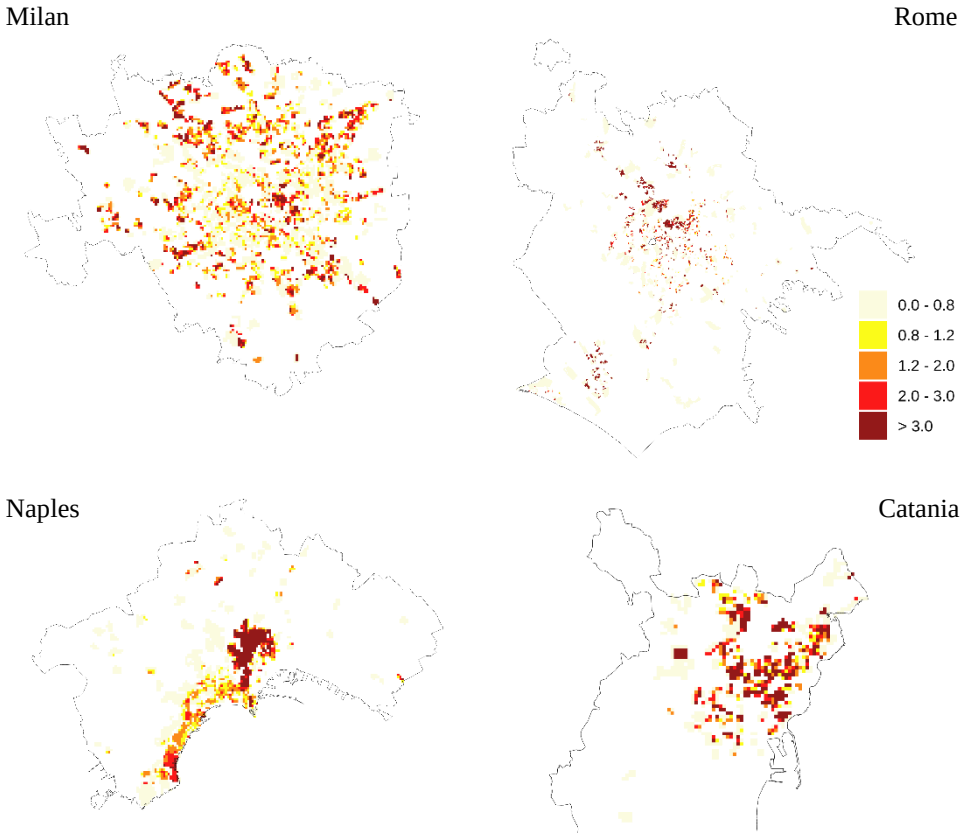
The Moran's *I* statistics for the residuals of the GWRR models (Table 2) reveal a consistently positive, albeit moderate, spatial autocorrelation across all cities, with a marginal deterioration in model performance over time, reflected also by a slight uptick in AICc values. This trend likely stems from evolving underlying processes that shape Sri Lankans' settlement behaviours. Examination of the local R^2 for each of the eight GWRR specifications (two GWRR per city: one for 2011 and one for 2021) indicates that the models generally capture the spatial variability in the data effectively, as exemplified by the local R^2 distribution for Milan in Figure 2. Minor

pockets of reduced fit may result from neglected explanatory factors or from non-linear associations between the predictors and the outcome.

Table 2 – *GWRR models' diagnostics*.

Year ->	2011		2021	
Municipality	AICc	Moran's I	AICc	Moran's I
Milan	32,831	0.39	35,069	0.58
Rome	61,744	0.27	64,089	0.36
Naples	8,331,441	0.41	8,716,744	0.49
Catania	5,514,937	0.34	5,591,848	0.38

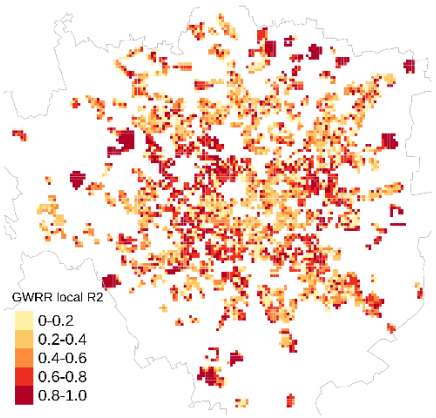
Figure 1 - *Sri Lankans' location quotients (ref. group: total resident population) in the four selected Italian municipalities, 2021. Spatial grid with 100 x 100 meters cells.*



The GWRRs unveiled pronounced spatial heterogeneity in the determinants of Sri Lankan settlement across the four Italian cities between 2011 and 2021 (Figure

3). In Rome, the employment rate (of the population aged 15-64) emerged as a consistently strong positive predictor of Sri Lankans' LQs in both census years. Areas in the northern semi-central districts and the EUR-adjacent southwestern periphery exhibited the highest local coefficients, indicating that zones with robust labour-market conditions continued to attract and sustain Sri Lankan communities over the decade. In Milan, rental cost displayed a marked spatial and temporal evolution. In 2011, lower rent levels across the broader periphery were significantly associated with elevated Sri Lankan concentrations; by 2021, this affinity shifted northward, concentrating on the city's outermost fringes.

Figure 2 – *Local R^2 in the municipality of Milan in 2021 (quantile breaks).*



Concurrently, the mean growth rate of the Italian population facilitated the gradual diffusion of enclaves: intermediate semi-central zones lost relative Sri Lankan share as new settlements emerged in more distal suburbs. Naples demonstrated enduring centralised clustering. The mean growth rate of foreign residents exerted its strongest positive influence around the historic core and the Chiaia district in both time points, underscoring the stability of established migrant networks and their role in reinforcing spatial concentration within these inner-city neighbourhoods. This result is not surprising given that Sri Lankans accounted for about the 25% of the total foreigners' growth during the period considered. In Catania, rental dynamics underwent a complete inversion. Northern semi-central areas, which had attracted Sri Lankan residents in 2011, became zones of repulsion by 2021. Instead, new pockets of attraction arose in the historic centre and the northern fringe. Meanwhile, the effect of Italian population growth, initially manifesting as a modest peripheral pull, vanished and subsequently re-emerged within the urban core, signalling a complex interplay between local demographic change and immigrant spatial behaviour.

Figure 3 – *GWRR selected results: covariates' coefficients in the four municipalities for the model referring to 2011 (left-hand figures) and 2021 (right-hand figures). Significance level: 5%. Note: non-comparable geographical scales.*

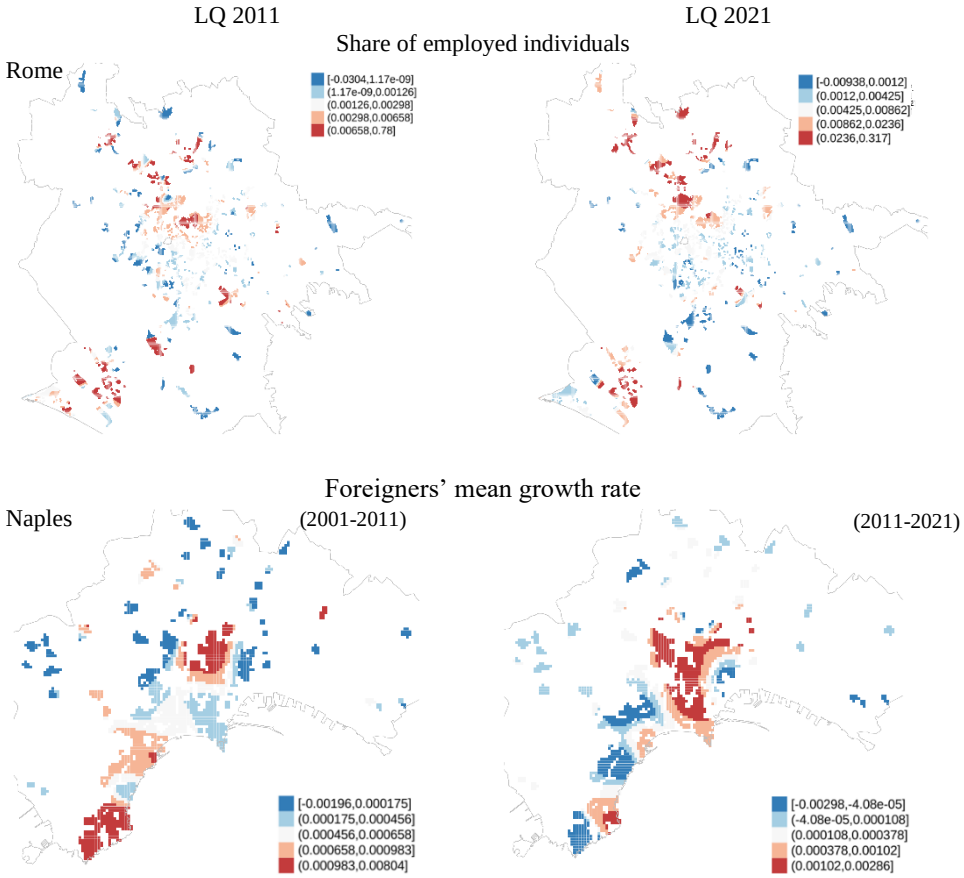


Figure 3 – cont. *GWRR selected results: covariates' coefficients in the four municipalities for the model referring to 2011 (left-hand figures) and 2021 (right-hand figures). Significance level: 5%. Note: non-comparable geographical scales.*

LQ 2011 LQ 2021

Minimum rent cost per m^2 for private residential properties

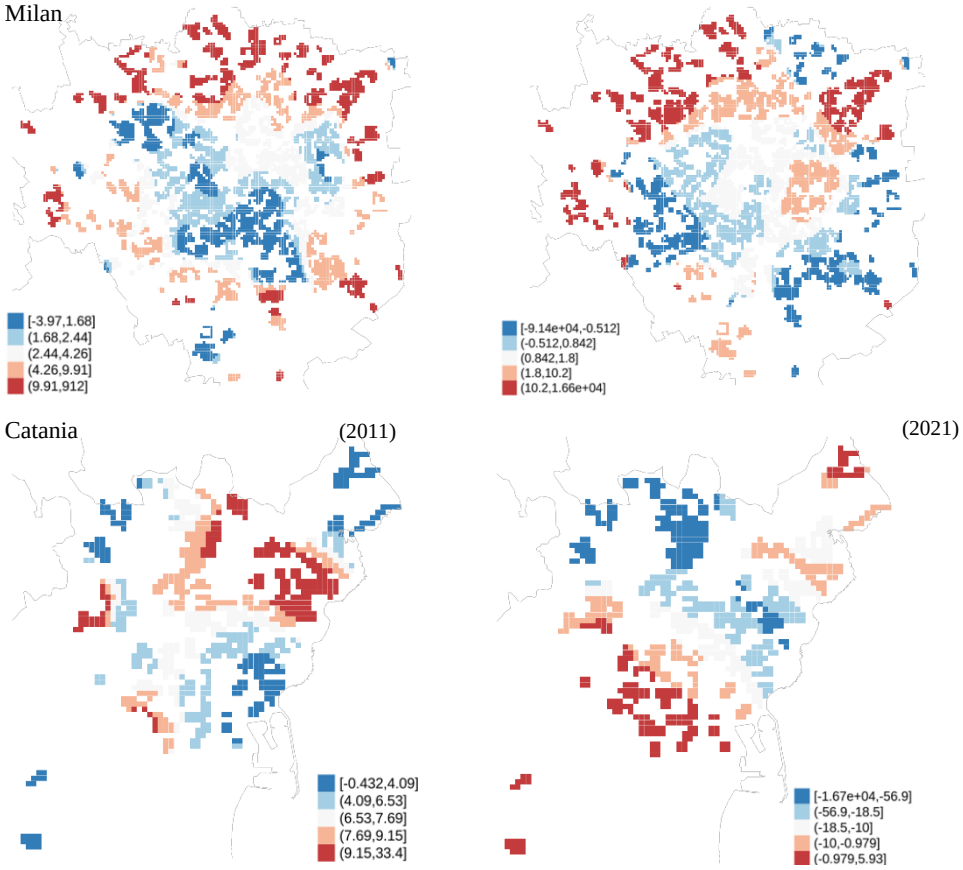
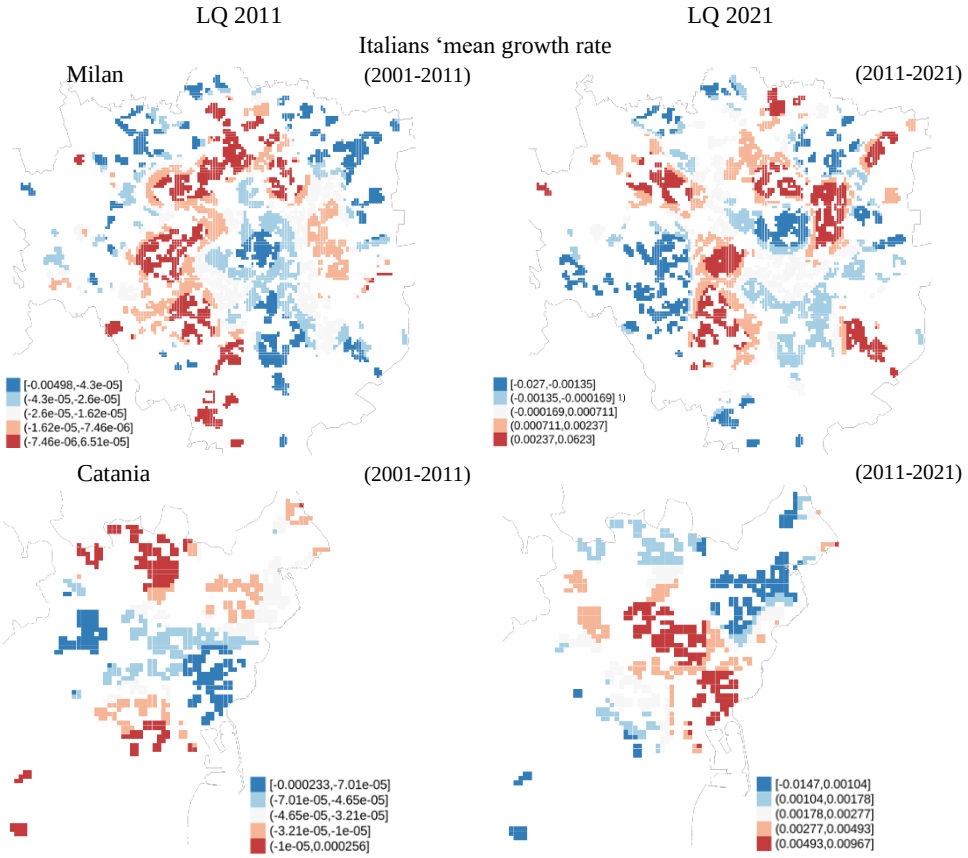


Figure 3 – cont. – *GWRR selected results: covariates' coefficients in the four municipalities for the model referring to 2011 (left-hand figures) and 2021 (right-hand figures). Significance level: 5%. Note: non-comparable geographical scales.*



4. Conclusions

This study demonstrates that integrating high-resolution spatially referred data with a GWRR framework effectively captures the spatial non-stationarity inherent in immigrant settlement patterns. The methodology offers a robust, transferable approach for demographic research, enabling fine-grained insights across multiple urban contexts.

By linking our findings to the three objectives formulated in the introduction, the analysis reveals the following:

First, regarding contextual variability, the results confirm that the spatial distribution of Sri Lankan residents diverges significantly across regional and metropolitan contexts: southern municipalities (Naples and Catania) exhibit pronounced ethnic clustering, whereas Rome and Milan display more spatially dispersed Sri Lankan communities. Temporally, settlement structures in Rome and Naples remained comparatively stable over the decade, while Milan and Catania experienced significant redistribution, reflecting divergent urban dynamics and housing-market pressures.

Second, with respect to driver identification, the local models reveal that heterogeneous factors underpin settlement dynamics in different cities. In Rome, labour market opportunities consistently emerge as strong positive predictors, reinforcing the link between employment and immigrant spatial concentration. In Naples, the enduring influence of established migrant networks underpins the persistence of central clustering. Milan shows the shifting relevance of rental affordability, which facilitated suburban diffusion before concentrating at the northern fringes. In Catania, rental market dynamics underwent a complete inversion, reflecting the complex interplay between housing costs and local demographic growth. These findings underscore the importance of considering structural, demographic, and cultural drivers jointly, as their relative weight varies across contexts.

Third, concerning temporal evolution, the comparative assessment between 2011 and 2021 reveals both stability and transformation. While Rome and Naples exhibit continuity in their settlement structures, Milan and Catania display significant redistribution processes. Such divergent trajectories mirror broader urban pressures, ranging from housing affordability to demographic change, that shape immigrant residential patterns over time.

These emerging trajectories stress the necessity for context-sensitive urban policies. In southern cities, sustaining the social cohesion benefits of clustering should be balanced with measures that prevent segregation and guarantee equitable access to services. In northern metropolises, planning interventions ought to accommodate peripheral diffusion by ensuring affordable housing and integrating new settlements into the urban fabric. Such targeted strategies will foster inclusive, resilient cities in an era of ongoing demographic transformation.

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